Bay of Quinte
Remedial Action Plan
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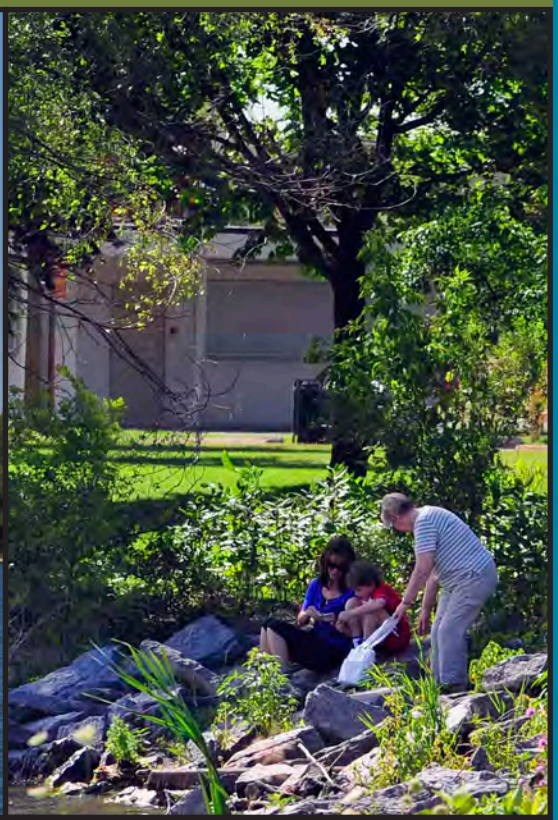
Bay of Quinte Remedial Action Plan Assessment Report

Beneficial Use Impairment
Degradation of benthos



February, 2017

Bay of Quinte Area of Concern

Beneficial Use Impairment Assessment Report
Degradation of Benthos

February 16, 2017

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Acknowledgements

The content of this beneficial use impairment assessment report and the three appended reports have been reviewed and approved by the Bay of Quinte Remedial Action Plan Benthos Technical Work Group, Delisting Steering Committee and Restoration Council. The following provides an amalgamated list of individuals who were involved in the writing, discussion, review and approval process for this report. The authors of the status reports are identified by an asterisk (*).

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Note: In 1986, the federal/provincial Bay of Quinte Remedial Action Plan Coordinating Committee was established to oversee the development of a Bay of Quinte Remedial Action Plan (RAP). The Coordinating Committee was charged with developing the RAP through parallel processes of technical evaluation and public participation. A Public Advisory Committee was established in 1988 to oversee the RAP public participation component. Both committees were dissolved in 1996 and in 1997 the Bay of Quinte RAP Restoration Council was formed, to oversee implementation of the RAP.

Executive Summary

This report provides an assessment of the status of the Bay of Quinte Area of Concern (AOC) impaired beneficial use 'Degradation of Benthos' and recommends that this beneficial use has been restored in the Bay of Quinte AOC.

Prior to 1970, benthic conditions in the Bay of Quinte were typical of a eutrophic system with large numbers of pollution-tolerant species. Phosphorus reduction strategies initiated in 1970 resulted in a less productive system, with a shift in the species composition to declining pollution-tolerant species and increasing pollution-sensitive species. However, the species composition in the early 1980s was considered to still be impaired. This led, in part, to the Bay of Quinte being identified as an AOC in 1987.

To address the bay's ecological problems, a Remedial Action Plan (RAP) was prepared in 1993 with goals to restore the impaired beneficial uses of the bay, with the intent of delisting the Bay of Quinte as an AOC under the Great Lakes Water Quality Agreement.

A restoration target was established in accordance with established RAP processes to assess the health of the benthic community of the Bay of Quinte over time: '*Using 1977-84 as the "base time period", demonstrate a positive trend and change in the benthic macroinvertebrate community structure of the Bay of Quinte*'. Three criteria were subsequently developed to determine when the target has been achieved.

Considerable work has been undertaken in the bay to reduce nutrient levels and increase water quality, which has had a positive impact on the benthic community. Phosphorus levels in sewage treatment effluent have been limited and extensive rural nutrient reduction programs have been undertaken.

The assessment of the bay against the delisting criteria determined the following:

> Criterion 1: The presence and increasing abundance of pollution sensitive benthic macroinvertebrate species in the Bay of Quinte that were absent in earlier community surveys.
> *Findings: Pollution sensitive species such as amphipods (shrimp-like), Pisidium (pea-clams) and gastropods have re-appeared in the bay where substrate conditions are favourable for these species.*
>
> Criterion 2: Acute and chronic sediment toxicity and benthic community composition and abundance are similar to suitable reference sites as determined by the BEAST methodology.
> *Findings: There was no strong evidence of degraded benthic communities at any sites analyzed within the Bay of Quinte. Most Bay of Quinte communities were regarded as either 'equivalent to reference', or at most, 'possibly different' from reference sites.*
>
> Criterion 3: Increased species and community diversity with the presence of various key benthic macroinvertebrate groups using an Index of Biotic Integrity methodology.
> *Findings: The various biotic indices used to assess the Bay of Quinte benthic community indicate that species density and diversity have increased and that many Bay of Quinte sites were as good, or better than, those for other lakes with good water quality.*

Key findings of this assessment report are:

- Deposition of sediment from agriculture and urban runoff has changed the physical characteristics of the bay's substrate in many areas. Areas which used to be hard substrates are now comprised of fine silts and clays with high organic content, constituting an unstable environment which limits the type of sensitive benthic species that can live there.
- The permanent introduction of invasive species such as zebra mussels and round goby has greatly affected the benthic populations. Zebra mussels cause a reduction in algal densities which limits food available to benthos, and the round goby further reduces benthic populations through heavy predation.
- By 2000, pollution sensitive species had re-appeared in the bay where substrate conditions were favourable for these species. Benthic community composition in the bay was compared to that of non-AOC reference sites, and it was determined that there were no marked differences between the benthic communities in terms of the dominant taxa.
- Sediment was found to be toxic at 3 out of 49 sites in the upper bay, although there was no strong concurrence with benthic community impairment. The benthic composition and abundance was generally similar to what could be expected given the habitat conditions.

Based on these findings, this beneficial use should be considered to be restored and the status of this beneficial use should be changed to 'not impaired' for the Bay of Quinte Area of Concern. Since 2000, the community structure has been stable, influenced by the local physical constraints such as invasive species and substrate composition.

1.0 Introduction

The Bay of Quinte was identified as an Area of Concern (AOC) in the 1987 Protocol to the U.S.-Canada Great Lakes Water Quality Agreement. This Agreement required the federal, state and provincial governments to develop and implement Remedial Action Plans (RAPs) for each AOC. The Bay of Quinte RAP Stage 1 Report (Bay of Quinte Remedial Action Plan Coordinating Committee 1990) identified the beneficial use 'Degradation of Benthos' as impaired in the Bay of Quinte AOC due to an altered benthic community as a result of nutrient enrichment. Eutrophication had resulted in a benthic community where there had been an overall decrease in numbers and taxa over time, an increase in the number of pollution-tolerant benthic species and a decrease in the number of pollution sensitive benthic species. This assessment of impairment was maintained in the 1993 Bay of Quinte RAP Stage 2 Report (Bay of Quinte Remedial Action Plan Coordinating Committee 1993).

Since 1972, the federal department of Fisheries and Oceans Canada (DFO) has monitored changes to the benthic community as part of Project Quinte following methods of Johnson and Brinkhurst (1971) and Johnson and McNeil (1986). Through Project Quinte, abundance and wet biomass of non-*Dreissena* macroinvertebrates were quantified once per year at 4 index sites in the bay, and sampling spanned several major environmental changes in the bay. These included: the post-phosphorus (P) reduction period (1982-1991); the post-zebra mussel period (1992-2001); and the post-goby period (2002-2010). Additional summer samples were periodically collected (1966-2001) along transects down the bay from Trenton to Amherst Island following the methods used by Johnson and McNeil (1986). Data on common species, community structure and diversity were compared to that occurring during the baseline period of 1977- 1984 to test if a positive trend and change had been demonstrated. Two biotic indices were used to compare the community in the Bay of Quinte to similar sites that had good water quality. An assessment of contaminated sediment within the Bay of Quinte and its impact on benthic communities was also undertaken. These assessments have contributed to the recommendation that this BUI be considered 'not impaired'.

Environment and Climate Change Canada (ECCC) began monitoring the benthic community of the Bay of the Bay of Quinte AOC in 2000 as a component of the Great Lakes Basin 2020 Action Plan Sediment Assessment Study. This was a five-year study to undertake a chemical and biological assessment of contaminated sediment in Canadian AOCs. The Benthic Assessment of Sediment (BEAST) methodology of Reynoldson et al (1995) was applied to the AOC assessments. This methodology involves the assessment of sediment quality based on the physico-chemical attributes of the sediment and overlying water, the structure of the benthic community and the functional response of benthic invertebrates in laboratory toxicity tests. Test site data are compared to biological criteria development for the Laurentian Great Lakes. The ECCC study in 2000 sampled 49 stations in the Bay of Quinte Area of Concern – 20 in the Belleville waterfront, 6 in the Trenton waterfront and the remainder were spread throughout the bay (Milani and Grapentine 2006). ECCC returned to the mouth of the Trent River in 2006 and 2011 to re-assess the status of conditions and determine trends over time (Milani 2011). The results of these studies have helped to inform the recommendation that this BUI be considered 'not impaired'.

The information contained herein is a summary of the following three reports, which are appended:

1) Golder (Golder Associates Ltd.). 2013. Assessment of Benthic Community Beneficial Use Impairments in the Bay of Quinte. Report to Environment Canada.

2) Dermott, R., 2012. Assessment of the Beneficial Use Impairment of Benthos in the Bay of Quinte. Fisheries and Oceans, Burlington, ONT. Unpublished report. March 2012.

3) Milani, D. 2011. Reassessment of 2000 and 2006 Benthic Community Structure for the Bay of Quinte. Environment Canada.

2.0 Targets and Criteria for Redesignating the Impaired Beneficial Use 'Degradation of Benthos'

In 1991, the International Joint Commission established the following redesignation guideline for this impaired beneficial use:

> *"When the benthic macroinvertebrate community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics. Further, in the absence of community structure data, this use will be considered restored when toxicity of sediment-associated contaminants is not significantly higher than controls."*

Based on this guideline, three delisting criteria were developed to assess this impaired beneficial use in the Bay of Quint Area of Concern. The criteria focused on the following:

1) The presence and abundance of pollution sensitive benthic macroinvertebrates,
2) Whether the benthic community was being impacted by sediment associated contaminants, and
3) Increased species and community diversity over time.

Table 2.1: Delisting targets and criteria for the Bay of Quinte Area of Concern.

DELISTING TARGETS	CRITERIA	STATUS
Using 1977-84 as the "base time period", demonstrate a positive trend and change in the benthic macroinvertebrate community structure of the Bay of Quinte.	1. The presence and increasing abundance of pollution sensitive benthic macroinvertebrate species in the Bay of Quinte that were absent in earlier community surveys.	Achieved
	2. Acute and chronic sediment toxicity and benthic community composition and abundance are similar to suitable reference sites as determined by the BEAST methodology.	Achieved
	3. Increased species and community diversity with the presence of various key benthic macroinvertebrate groups using an Index of Biotic Integrity methodology.	Achieved

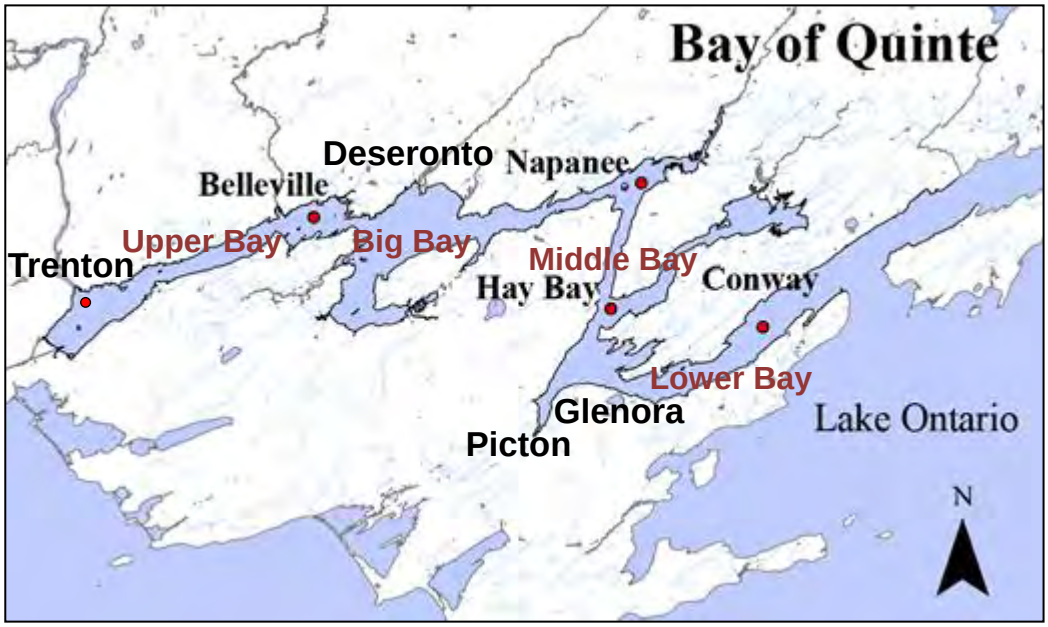


Figure 2.1: Map of key areas in the Bay of Quinte Area of Concern.
The red dots represent the areas where benthic sampling was concentrated: Trenton, Belleville, Napanee, Hay Bay, Conway. Additional sampling sites were located throughout the bay.

3.0 Beneficial Use Impairments

Substantial changes to the Bay of Quinte benthic community took place when regulations to reduce the use of phosphorus came into effect in the 1970s, as well as when *Dreissena* (zebra and quagga mussels) became established in the 1990s and the round goby (*Neogobius melanostomus*) in the early 2000s. The shifts in the ecosystem due to these factors were so distinct, that the following time stanzas can be distinctly seen. These have been used to frame many of the following discussions:

- 1967 to 1978: pre-phosphorus control period.
- 1982 to 1991: post-phosphorus time period, describing the years after phosphorus loading from sewage treatment plants had been substantially reduced.
- 1992 to 2001: post-*Dreissena* time period, referring to the time period after *Dreissena* arrived (1991) then became established in the bay (1993).
- 2002-2010: post-goby establishment period.

As well as invasive species out-competing native benthic species for food and space, problems with changes to the substrate due to urbanization have also had an impact on the benthic species composition in the Bay of Quinte.

3.1 Phosphorus

High phosphorus loadings to the Bay of Quinte had a significant negative impact on the benthic species richness and diversity. The loadings resulted in increased algae growth, decreased water clarity and lower oxygen levels on the bottom of the bay during the summer. This in turn resulted in significant decreases in both benthic species richness and diversity (Bay of Quinte Remedial Action Plan Coordinating Committee 1990). Additionally, the number of pollution tolerant species increased and the number of pollution sensitive species decreased. The effects were seen more severely in the upper and middle bays than in the lower bay which is influenced in a large part by the water quality of Lake Ontario.

3.2 Invasive Species

The impact of the invasive *Dreissena* and the round goby had as much effect on the environment and benthic fauna in the Bay of Quinte as did the degraded water quality in the pre-phosphorus control period.

Dreissena arrived in the Bay of Quinte in 1991, becoming common within the aquatic community by 1993. Their arrival resulted in increased water clarity, a change in the phosphorous regime and an increase in macrophytes (Dermot 2010). They also heralded the disappearance of the amphipod *Diporeia* which was replaced by extensive colonies of quagga mussels on the soft sediments (Dermott 2010) Diporeia disappeared at the Conway site in 1993 and at the outlet of the Bay of Quinte to Lake Ontario in 1994 (Dermott 2001), and have not been found since. This amphipod had been the main component in the food-web of the lower Bay of Quinte and Lake Ontario. The freshwater clams *Sphaerium* and *Musculium,* both indicators of a healthy ecosystem, also disappeared from the Bay of Quinte benthic community by 1999, due to direct competition with *Dreissena* for food (Dermott 2010). By 2004, the total non-*Dreissena* biomass in the bay had displayed a decreasing trend since the arrival of *Dreissena* in the early 1990's (Dermott 2006) (Figure 3.1).

In the lower bay, biomass of the other non-dreissenid benthos greatly decreased at all sites after the loss of the *Diporeia hoyi* amphipod (Figure 3.1). At Conway, the amount of tissue biomass bound up by the mussels including their shells was over 390 times that of all other invertebrates from 2008 - 2010. The resources needed to maintain this huge mussel biomass comes at the expense of the other benthic species such as the zooplankton and the sediment bacteria that prior to 1990 would have consumed the bay's phytoplankton production.

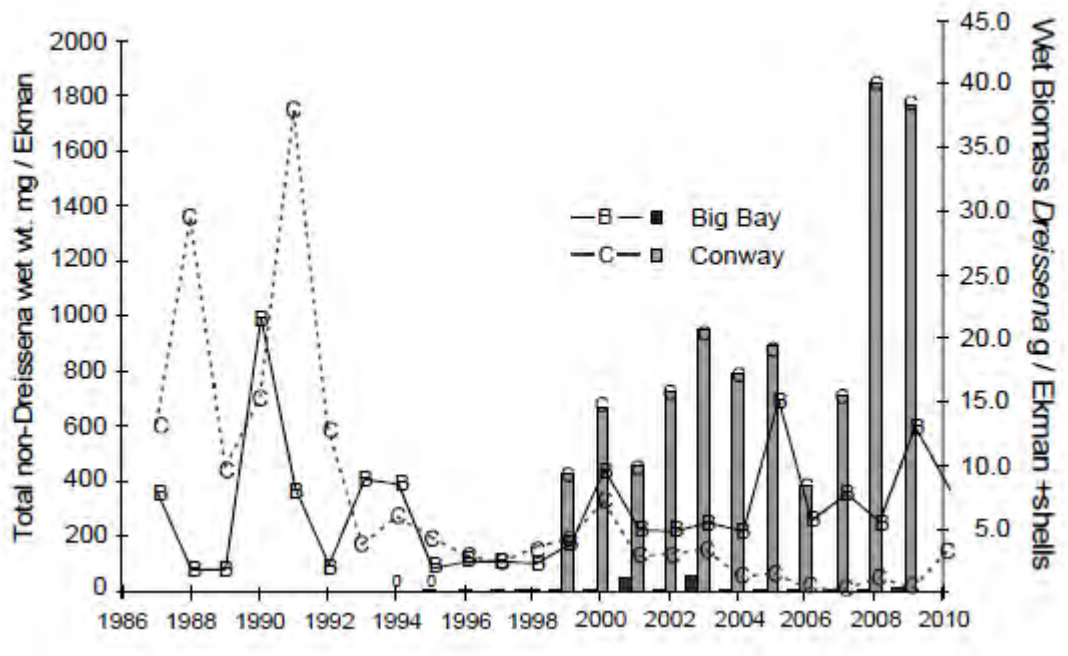


Figure 3.1: Wet biomass of non-*Dreissena* and *Dreissena* at Big Bay (Upper Bay) and Conway (Lower Bay) (Dermott 2012). The lines depict non-Dreissena biomass and the bars depict Dreissena biomass.

The invasive round goby was first found in the Bay of Quinte in 1999 and by 2002 had become dominant in the near shore areas. The round goby increased predation pressure on the benthic species, likely contributing to the decrease in non-*Dreissena* benthic biomass. The littoral community in the Bay of Quinte is now much less diverse than in 1990 as many of the riverine species have since declined, being out-competed by the invading zebra mussels or eaten by the abundant round gobies (Barton et al. 2005; Haynes et al. 2005).

3.3 Effects of Changes to Substrate

There is a direct relationship between sediment substrate type and the benthic communities that became established in those substrates. Burrowing species, which include most pollution tolerant oligochaetes and a large number of the chironomid and small mussel species, are limited in their habitat preference to areas of soft sediments. Many of the common pollution sensitive species such as mayflies, stoneflies and caddisflies, are more common on hard substrates.

Over the past 200 years, the development of the urban and rural areas around the Bay of Quinte has resulted in exacerbated erosion and sedimentation, changing the characteristic of many substrates from hard rock to soft sediment. As a result, depositional areas of fine sediments such as at the mouth of rivers and along the shoreline will naturally favour the establishment of communities dominated by the more pollution-tolerant chironomids and oligochaetes. *Diporeia hoyi*, the pollution-sensitive amphipod, disappeared from the Bay of Quinte in 1996. It is believed that an increase in sediment loading in conjunction with competition from invasive species were the responsible factors (Golder 2013). These permanent changes to the physical substrate in the Bay of Quinte have been taken into consideration during this assessment of the benthic communities.

4.0 Actions Undertaken to Address the Beneficial Use Impairments

There have been significant efforts undertaken to reduce the input of phosphorus to the Bay of Quinte, which has been positively affecting the benthic communities.

4.1 Reduction of phosphorus loading

To address the impacts associated with eutrophication in the Bay of Quinte, the amount of total phosphorus entering into the bay on a daily basis has been substantially reduced since the 1970s as a result through the implementation of many different types of programs. Government restrictions and voluntary municipal commitments have been the key forces driving this decrease in loadings.

4.1.1 Government restrictions on phosphorus use

By 1959, almost all laundry detergents from the United States contained between 7 – 12% phosphorus gross dry weight. By 1969, some detergents contained between 15% - 17% and it was estimated that half of the phosphorus input to Lake Ontario came from municipal and industrial sources, of which 50% - 70% came from detergents (Knud-Hansen 1994). To address these excess loads, Canada Water Act was enacted in 1970 which immediately limited phosphorus to 8.7% in laundry detergent, with a further reduction to 2.2% phosphorus by the end of 1971.

On July 10, 2010 the *Regulations Amending the Phosphorus Concentration Regulations*, pursuant to the Canadian Environmental Protection Act (1999), came into effect which broadened the scope of existing regulations to include additional detergents and cleaners, and lowered the limits on allowable phosphorus concentrations in dishwater detergents to 0.5% or lower (Environment and Climate Change Canada 2015).

4.1.2 Restrictions on effluent limits from waste water treatment plants

The amount of total phosphorus in municipal sewage treatment plant (STP) effluent from plants bordering the Bay of Quinte has been monitored since the late 1960s. From 1965 to 1972, the daily average total phosphorus loading from the STP effluent was 214 kg d^{-1}. Since then, controlling the variability in wastewater flow, enhancing phosphorus removal capabilities and expanding treatment capacity has resulted in the daily average phosphorus load from these STPs to decrease to 5.6 kg d^{-1} by 2012 (Kinstler and Morley 2014).

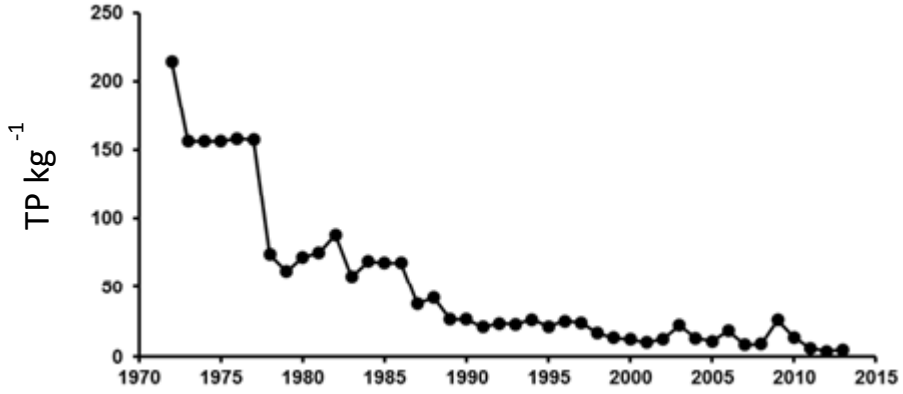


Figure 4.1: Point-source phosphorus loading to the Bay of Quinte kg $^{-1}$ (Kinstler and Morley 2014).

A key action for achieving the STP loading reductions was the restriction on effluent limits for STPs in the Bay of Quinte watershed. In the early 1990s, the MOECC initially instituted a 'phosphorus cap' at plants which discharged directly into the bay, limiting their total phosphorus effluent concentration from 1.0 mg l^{-1} to 0.3 mg l^{-1}. Since 1995, most of the municipal waste water treatment plants have voluntarily reduced total phosphorus inputs or have undertaken infrastructure upgrades and the "phosphorus load cap" has been incorporated into their operating Environmental Compliance Approval (ECA) (Kinstler and Morley 2014). The phosphorous load cap approach was broadened after 1995 to include STPs in the bay's watersheds; these STPs are required to limit their total phosphorus effluent concentration to 0.5 mg l^{-1}.

Industrial sources of phosphorus have also decreased as a result of the introduction of the provincial Municipal-Industrial Strategy for Abatement (MISA). This program was developed in the 1990s under the Environmental Protection Act to regulate industrial discharge of contaminants. Phosphorus discharge from three key industries in the Bay of Quinte AOC – Strathcona Paper Co., Sonoco and Norampac (Domtar) – is regulated under the MISA regulation 'Effluent Monitoring and Effluent Limits – Pulp and Paper Sector' (Ontario Ministry of the Environment 2007a). These companies routinely meet or are below the MISA requirements for phosphorus loading (Andrew Morley, pers. communication). The Bay of Quinte RAP recommends more stringent effluent guidelines for phosphorus than those found in the MISA regulation. The RAP objective is to limit effluent concentrations to 0.5 mg l^{-1} total phosphorus, but this limit has not yet been incorporated into the ECAs for all the three local industries.

4.1.3 Rural stewardship programs

The Bay of Quinte RAP Rural Water Quality Program was started in 1992 to implement the RAP recommendations on decreasing diffuse source loadings of contaminants within the Bay of Quinte watershed. Projects included repairing septic systems, introducing conservation tillage, livestock fencing, and improving manure storage and milkhouse waste disposal systems (Stride 1997). Between 1994 and 2002, the reduction in tributary loadings of phosphorus delivered to the bay from agricultural diffuse sources through the Rural Water Quality Program was estimated to be 16,500 kg/year (Tejani and Muir 2004). Efforts to reduce phosphorus loadings from agricultural landuses are continuing around the bay. Septic inspections, a Healthy Soils Check-up Program to monitor levels of phosphorus in agricultural fields, and shoreline restoration programs are being focused in areas that are highly susceptible to erosion

and where receiving waterbodies have high levels of phosphorus.

4.1.4 Stormwater management

The Bay of Quinte RAP Stormwater Quality Program was introduced in 1992 to provide opportunities through effective planning and resource management to achieve the Bay of Quinte RAP target of a 'No Net Increase' in contaminant loading from areas of new and expanding urban development. Stringent stormwater quality criteria were developed, adopted and implemented for the 16 municipalities bordering directly on the Bay of Quinte. As a result, a number of effective stormwater management facilities have been constructed and many innovative planning tools prepared. The South Sidney, Potter Creek, and Dead and York Creek subwatershed plans were developed in the 1990s in part to meet the environmental standards set by the Bay of Quinte RAP (Stride 1997). The Bay of Quinte RAP guidelines have also been endorsed in the Official Plans of all municipalities surrounding the bay.

The Bay of Quinte Remedial Action Plan Stormwater Management Plan Guidelines, 2006, provide the basic guidelines for submission and review process for all developments within the implementation area of the Bay of Quinte RAP. The guidelines are relevant for all townships fronting on the Bay of Quinte within the jurisdictions of the Quinte, Lower Trent and Cataraqui Region conservation authorities. Pollution Prevention and Control Plans have been developed in partnership with the RAP for Belleville, Quinte West, Picton, Napanee and Deseronto, to address stormwater runoff from urban areas. These plans are now being used to guide stormwater facility development throughout the region.

5.0 Beneficial Use Assessment: Results and Recommendations

Criterion 1: The presence and increasing abundance of pollution sensitive benthic macroinvertebrate species in the Bay of Quinte that were absent in earlier community surveys.

The large phosphorus inputs to the Bay of Quinte throughout the 1960s and early 1970s had a significant negative impact on the benthic community. Excess phosphorus enabled an increase in the growth of algae including nuisance blue-green forms, and lowered oxygen levels on the bottom during summer which reduced the types of benthic species that could live in the bay.

As phosphorus inputs to the bay diminished in the 1970s, substantial changes to the benthic community were seen. Pollution tolerant species began to decline. Pollution sensitive species such as the native pea clams reappeared, and other pollution sensitive species became more abundant. By 1995, several pollution sensitive species of oligochaete worms, chironomid midges, amphipod shrimps, and gastropod snails that had been rare in the upper bay before 1982 became more abundant at the Big Bay site (Figure 5.1).

Over time, pollution sensitive species of worms, midges, and crustacea either re-appeared or appeared for the first time in the samples from both the upper and lower bay. The delisting target of a positive trend and change in composition was reached as the increase of less common species reduced the dominance of pollution tolerant species that had been most common during 1977 – 1984. A list of these species and their relative abundances is presented in the more detailed report by Dermott (2012).

The clean water indicator mayfly *Hexagenia* re-appeared briefly in the upper bay at the narrows near Way Point and Massasauga Point in 1987-1989, and occurred periodically in the lower bay, especially between Picton and Glenora, from 1991 until present. This mayfly requires adequate oxygen to be present on the bottom each day over its two-year life cycle and thus has been used as an indicator of good water quality over a long time span.

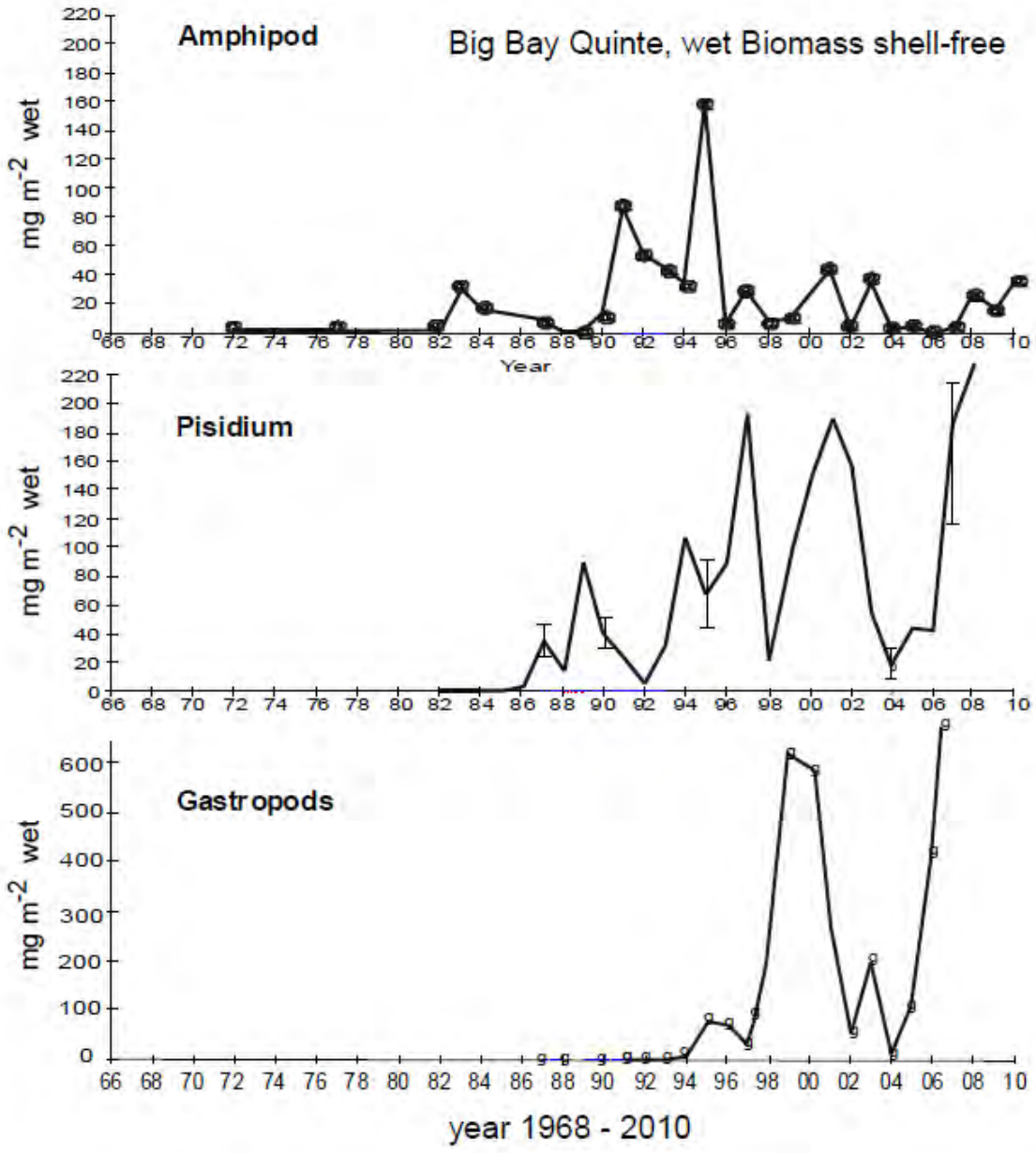


Figure 5.1: Shell-free wet biomass (mg/m^2) of pollution sensitive amphipods (shrimp-like), *Pisidium* (pea-clams) and gastropods (snails) at Big Bay (Dermott 2012).

Recommendation: Criterion 1 has been met since 2000. Benthic communities are currently being stressed by broader factors such as successive waves of invasive species which have affected not only the Bay of Quinte but large areas of the lower Great Lakes. These represent a permanent change to the Bay of Quinte as well as to the broader Great Lakes. However, pollution sensitive species have re-appeared in the bay where substrate conditions are favourable for these species. Based on the re-appearance of sensitive species, this criterion is considered to be met.

Criterion 2: Acute and chronic sediment toxicity and benthic community composition and abundance are similar to suitable reference sites as determined by the BEAST methodology.

In 2000, the BEAST methodology was applied to 49 sites in the Bay of Quinte: 20 in the Belleville waterfront, 6 in the Trenton waterfront and the remainder were spread throughout the bay. The study found local sediment toxicity at sites of the 49 sites examined, these being situated near the Moira and Trent Rivers, but no benthic community impairment was found. At 48 of the 49 sites, the benthic community was similar to that from a range of reference sites with similar habitat and sediment characteristics. Only one site, at the mouth of the Moira River, showed evidence of sediment toxicity with mild benthic community impairment in the form of low taxon richness. Figure 5.2 shows the location of the 49 sampling sites from 2000 (Milani 2011).

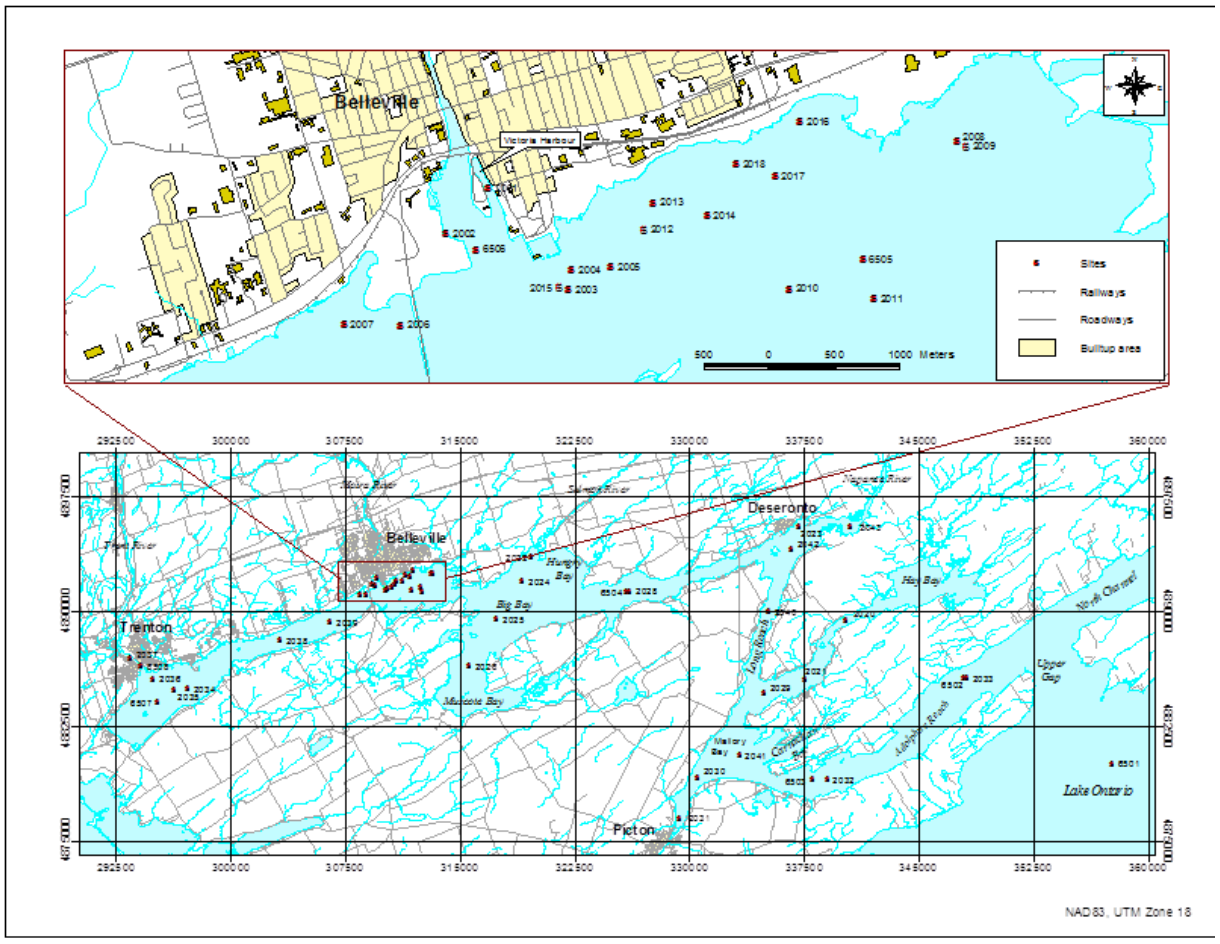


Figure 5.2: BEAST sampling sites in the Bay of Quinte, 2000 (Milani 2011).

In 2006 and 2011, sediment quality in the lower Trent River was re-assessed in areas where elevated levels of dioxins and furans had been found through other studies. The 2006 study identified that potential toxicity (chronic) was evident but there was no evidence of highly degraded benthic communities (Milani 2011).

The 2011 study again found that there was no strong evidence of degraded benthic communities at any sites. There was some lower taxon richness and abundance, but the study was unable to differentiate whether the benthic communities were being impacted by sediment contaminants or habitat related factors. Most Bay of Quinte communities were regarded as either ‘equivalent to reference’, or at most, ‘possibly different’ from reference sites (Milani 2011).

Recommendation: Criterion 2 had been met by 2000. The benthic assemblages are similar to what could be expected given the habitat conditions with the exception of one site in the Belleville area due to decreased abundance of dominant taxa (chironomids and oligochaete worms) compared to reference. Sediment toxicity is localized to a few areas, but there is no concurrence with benthic impairment at these sites.

Criterion 3: Increased species and community diversity with the presence of various key benthic macroinvertebrate groups using an Index of Biotic Integrity methodology.

Species richness is the total number of species present in a given area or sample, and species diversity takes into account how individuals are distributed among the species present (Aslam 2009). Species diversity and richness are used as indices of water quality in lakes and streams. Community diversity looks at all the different kinds of species in a given area or sample, not just benthic for this purpose.

In this study, **species diversity** was examined using the Margalef Diversity index, which can make comparisons between communities or over time for the same community (Margalef 1958). Margalef diversity values in stressed communities dominated by a few species, such as in the Hamilton Harbour AOC, are usually less than 1. A value of 3 is typical of a moderately diverse community, but values can exceed 5.0 in very diverse communities such as Inner Long Point Bay on Lake Erie, or Tobermory on Georgian Bay. Figure 5.3 shows that the benthic species diversity in the Bay of Quinte has increased since the 1970s and is typical of a moderate to diverse community.

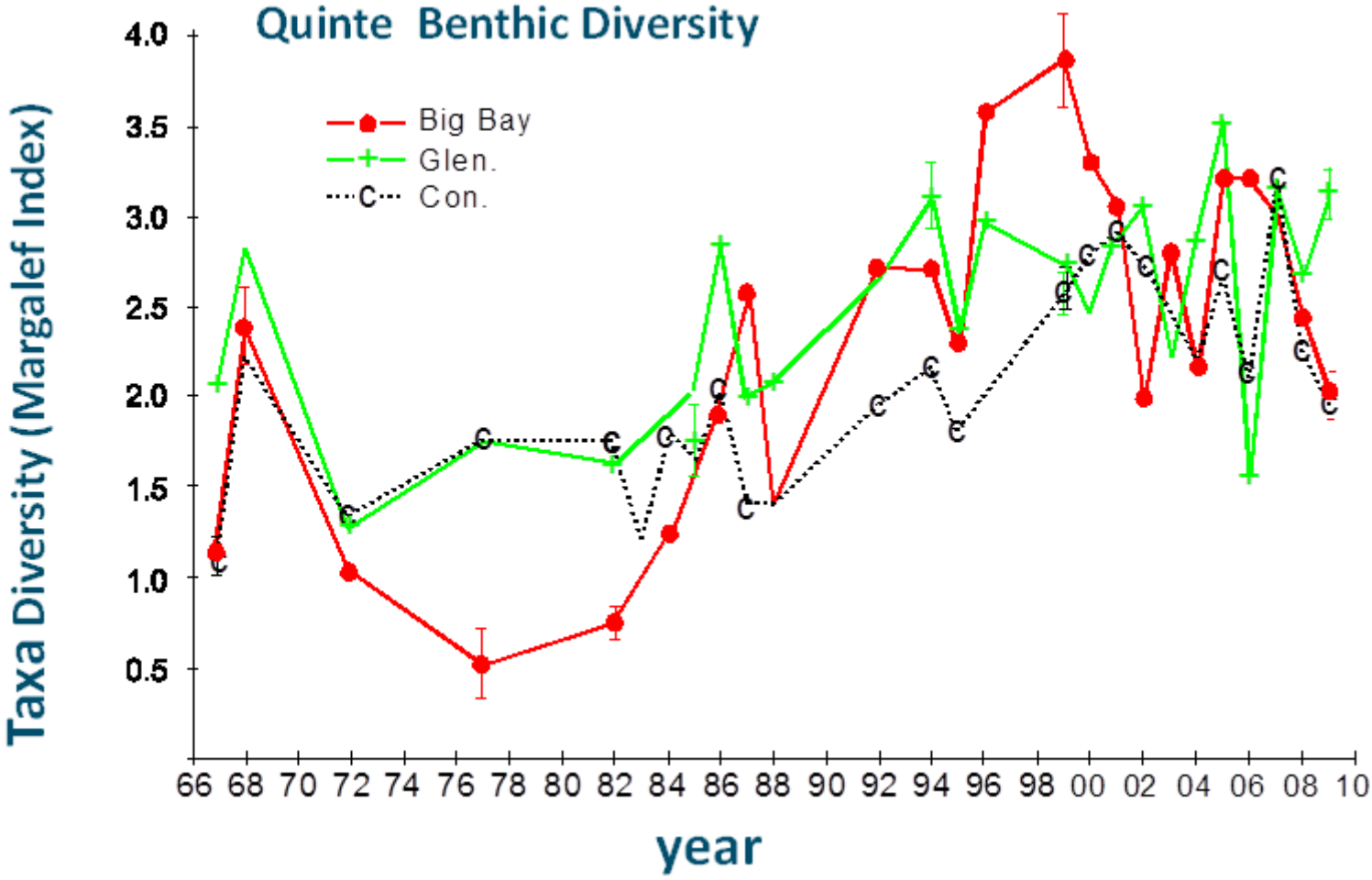


Figure 5.3: Trend in benthic diversity using the Margalef Diversity Index at the Big Bay (Upper Bay), Glenora (Middle Bay) and Conway (Lower Bay) index sites (Dermott 2012).

The delisting target of increased species diversity has been met within the Bay of Quinte. Starting in the mid-1970s, as the phosphorus inputs to the bay decreased, the number of benthic species increased.

In 1990, prior to *Dreissena*'s arrival, several riverine insects such as Hydropsychid caddisflies, water-pennies (Psephenidae), and winter-stoneflies (Capniidae) were common in the wave zone at Big Island. These benthic species are indicators of excellent stream water quality, indicating that by 1990 the upper Bay of Quinte had supported a rich and healthy littoral community.

From 1972 until 2005, benthic diversity increased at both Big Bay and Glenora from <1.3 to 3.12 and 3.55 respectively, as water quality improved and aquatic plant beds expanded.

Since 2004, diversity at Big Bay, Glenora and Conway fluctuated at values (2.2 - 3.5) which still indicated a moderate to diverse benthic community (Figure 5.3).

The Bay of Quinte benthic **community diversity** was evaluated using the Lake Biotic Index (LBI) in the Bay of Quinte in 1966, 1989 and 2001 (Dermott 2012). This index measures the macroinvertebrate biodiversity of the community inhabiting soft sediments in the littoral zone compared to that in the deeper zone of the lakes, due to changing temperature, oxygen levels and lake functional capacity. The LBI (Figure 5.4) indicated that conditions at Trenton (T) and in the lower bay (LQ) improved between 1966 and 1990. The further the data point is to the top-right quadrant of the graph, the more diverse is the benthic community. In 2001 conditions had slightly decreased due to a huge density of *Dreissena* in the Big Bay (BB) samples but still indicated a rich littoral community. LBI scores for Big Bay and the lower bay indicated no restriction to the benthic community due to sediment or oxygen conditions.

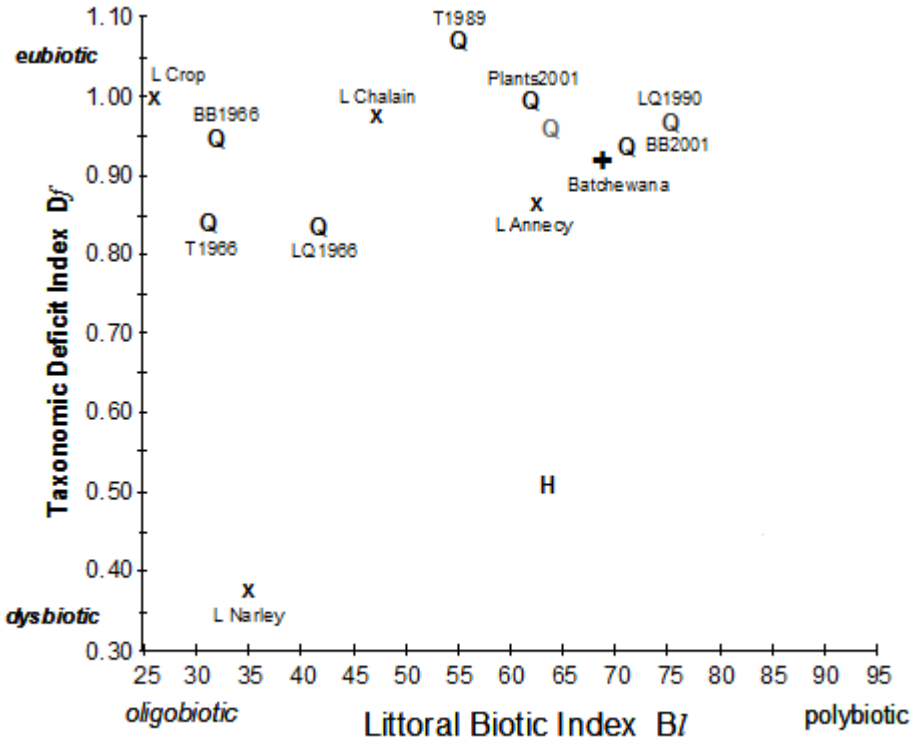


Figure 5.4: Plot of the littoral biotic index (BI) and taxonomic deficit index (Df) used in the calculations for the Lake Biotic Index (Verneaux et al. 2004) from several transect surveys in the Bay of Quinte (**Q**), Batchawana Bay (**+** Lake Superior), and Hamilton Harbour (**H**). Data for French lakes (**X**) from Borderelle et al. 2005. Comparative Batchawana Bay and Hamilton Harbour data from Department of Fisheries and Oceans (Dermott 2012). The sampling year is identified at each data point.

Recommendation: Criterion 3 has been met. The various biotic indices used indicate that species density and diversity have increased. A number of indices were used to assess benthic communities, with concordance among them, indicating that many Bay of Quinte sites were as good, or better than, those for other lakes with good water quality.

6.0 Conclusions and Recommendation

The benthic community of the Bay of Quinte Area of Concern has changed significantly over time. Phosphorus loadings from waste water treatment plants, storm sewer effluent and rural agricultural practices have permanently altered the ecological structure and water quality of the bay. There have also been losses of major common benthic species due to competition for food and space with invasive species, and decreases of non-*Dreissena* biomass due to significant expansion of the *Dreissena* populations. The substrate of the bay has also changed, reducing the quantity and quality of habitat for pollution intolerant species which are more common on hard substrates.

These permanent changes to the ecosystem mean that the benthic community is never going to revert back to a community similar to one prior to the appearance of invasive species. However, the various studies assessed for this report have determined that the current benthic community is similar to that from Great Lakes references sites, species diversity has increased over time, and there has been a resurgence of pollution-sensitive species and a decrease in pollution tolerant species. Current impacts on benthos are now due to invasive species and substrate-related changes, not due to pollution stressors as originally identified in the Bay of Quinte RAP Stage 1 Report.

Based on the above analysis, the conditions in the Bay of Quinte AOC show that the ‘Degradation of Benthos” beneficial use has been restored and that this beneficial use should be considered as ‘not impaired’ in the Bay of Quinte Area of Concern.

7.0 Future Monitoring Requirements

Since the benthic community has been stable since 2000, benthic monitoring on a site-by-site basis should be considered if changes to the water quality and/or sediment quality of the Bay of Quinte are identified. This would be undertaken through already-established long-term water quality monitoring programs undertaken by local agencies such as conservation authorities.

8.0 References

Aslam, M. 2009. Diversity, species richness and evenness of moth fauna of Peshawar. Pak. Emtomol., 31(2): 99-102.

Barton, D.R., Johnson, R.A., Campbell, L., Petruniak, J., & Patterson, M. 2005. Effects of round gobies (*Neogobius melanostomus*) on dreissenid mussels and other invertebrates in eastern Lake Erie, 2002-2004. J. Great Lakes Res. 31 (Suppl. 2): 252-261.

Bay of Quinte Remedial Action Plan Coordinating Committee. 1990. Stage 1: Environmental Problem Setting and Problem Definition.

Bay of Quinte Remedial Action Plan Coordinating Committee. 1993. Time to Act - The Bay of Quinte Remedial Action Plan Stage 2 Report.

Stride, F. 1997. 1995 Implementation Highlights. In Project Quinte Annual Report 1995 Monitoring Report #7: 3 – 6.

Biberhofer, J., & Dunnett, M.P. 2006. Summary of recent sediment investigations for the Bay of Quinte, Lake Ontario. Environment Canada. National Water Research Institute. NWRI 06-229, September 2006.

Borderelle, A.L., Verneaux, V., & Gerdeaux, D. 2005. Biological quality assessment of three French Alpine lakes (Lake Annecy, Lake Crop, Lake Grand Domenon) using the Lake Biotic Index (LBI). Arch. Hydrobiol. 162: 497-509.

Dermott, R., 2001. Sudden disappearance of the amphipod Diporeia from eastern Lake Ontario: 1993 - 1995. J. Great Lakes Res. 27: 423-433.

Dermott, R., 2006. Benthic Fauna in the Bay of Quinte. In Bay of Quinte Remedial Action Plan Monitoring Report #15: 78-88.

Dermott, R., 2010. Changes to the Benthic Fauna in the Bay of Quinte over 40 Years. Fisheries and Oceans, Burlington, Ontario. Unpublished report. June, 2010.

Dermott, R., 2012. Assessment of the Beneficial Use Impairment of Benthos in the Bay of Quinte. Fisheries and Oceans, Burlington, ONT. Unpublished report. March 2012.

Dermott, R., & Pachkevitch, A. 2012. Biotic Indices of the Littoral Benthic Community from the Bay of Quinte, eastern Lake Ontario. Can. Manuscr. Rep. Fish. & Aquat. Sci. 2996. 35 pp.

Environment and Climate Change Canada. 2015. Current Regulations. <https://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=17> retrieved from Government of Canada website on October 25, 2016.

Gandhi, N., Diamond, M., Razavi, R., Bhavsar, S., Hodge, E., Gewurtz, S., & Arhoditsis, G. 2014. A modelling assessment of contaminant fate in the Bay of Quinte, Lake Ontario: Part 2. Organic chemicals. Aquatic Ecosystem Health and Management, 17 (2): 137-150.

Golder (Golder Associates Ltd.) 2012. Great Lakes Areas of Concern: Review of the "Restrictions on Dredging" Beneficial Use Impairment. Report to Environment Canada. May 2012.

Golder (Golder Associates Ltd.). 2013. Assessment of Benthic Community Beneficial Use Impairments in the Bay of Quinte. Report to Environment Canada.

Griffiths, R.W. 1999. BioMAP: Bioassessment of water quality for southern Ontario watercourses. (Published by Niagara College, Glendale Campus, Niagara on the Lake, Ontario. 110 pp) revised sensitivity values from web link BIOMAP CENTRAL Appendix of Sensitivity Values. <http://www.execulink.com/~bugman/> retrieved on September 14, 2016.

Griffiths, R., & Muter, M. 2003. Water quality along the southeastern shoreline of Georgian Bay in 2003. Report to the Georgian Bay Area (GBA) Foundation. December 2003.

Haynes, J.M., Tisch, N.A., Mayer, C.M., & Rhyne, R.S. 2005. Benthic macroinvertebrate communities in southwestern Lake Ontario following invasion of *Dreissena* and *Echinogammarus*: 1983 to 2000. J. North. Amer. Benth. Soc. 24: 148-167.

Johnson, M.G., & Brinkhurst, R.O. 1971. Associations and species diversity in benthic macroinvertebrates of Bay of Quinte and Lake Ontario. J. Fish. Res. Bd. Canada 28: 1683-1697.

Johnson, M.G., & McNeil, O.C., 1986. Changes in abundance and species composition in benthic invertebrate communities of the Bay of Quinte, 1966-84. Can. Spec. Publ. Fish. Aquat. Sci. 86, 177-189.

Kinstler, P. & Morley, A. 2016. Point Source Phosphorus Loadings: 1965 to 2014. In Bay of Quinte Remedial Action Plan Monitoring Report #25: 21–23.

Knud-Hansen, C. 1994. Historical perspective of the phosphate detergent conflict. Conflict Resolution Consortium, University of Colorado at Boulder.

Margalef, R., 1958. Information theory in ecology. Gen. Syst. 3, 36-71.

Marvin, C.H. 2015. 2014 Trent River Suspended Sediment Survey Report. Environment and Climate Change Canada.

Milani, D. 2011. Reassessment of 2000 and 2006 Benthic Community Structure for the Bay of Quinte. Environment Canada.

Milani, D., and Grapentine, L.C. 2006. Assessment of sediment quality in the Bay of Quinte Area of Concern, 2000. NWRI contribution No. 04-002, July 2006. Environment Canada, Water Science Technology Directorate, Burlington, Ontario. 43 pp.

Noble, R. 2015. Historic Deloro mine returns to nature. Can.Min.J. 136 no.2, 20-23.

Ontario Ministry of the Environment. 2007a. Effluent Monitoring and Effluent Limits – Pulp and Paper Sector, O. Reg. 259/11, <https://www.ontario.ca/laws/regulation/930760> retrieved on October 25, 2016.

Ontario Ministry of the Environment. 2007b. Environmental Risk Assessment for the Trent River Mouth Sediment Depositional Areas. Project No. 07-7375, Dillon Consulting Limited.

Ontario Ministry of the Environment and Climate Change. 2015. Director's Order: Belleville's Former Manufactured Gas Plant Site. August 31, 2015. http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2015/012-3873.pdf retrieved on October 25, 2016.

Persaud, D., Jaagumagi, R., & Hayton, A. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of Environment and Energy Report.

Reynoldson, T. B., Bailey, R. C., Day, K. E. & Norris, R. H. (1995), Biological guidelines for freshwater sediment based on BEnthic Assessment of SedimenT (the BEAST) using a multivariate approach for predicting biological state. Australian Journal of Ecology, 20: 198–219.

Tejani, R., & Muir, T. 2004. Economic Benefits of the Bay of Quinte Remedial Action Plan (1994-2002). Environment Canada. August 2004.

Trent River Administrative Controls Committee. 2011. Lower Trent River Sediment Strategy Evaluation of Administrative Controls.

Verneaux, V., Verneaux, J., Schmitt, A., Lovy, C., & Lambert, J.C. 2004. The Lake Biotic Index (LBI): an applied method for assessing the biological quality of lakes using macrobenthos; the Lake Chålain (French Jura) as an example. Annls. Limnol. - Int. J. Limnol., 40: 1-9.

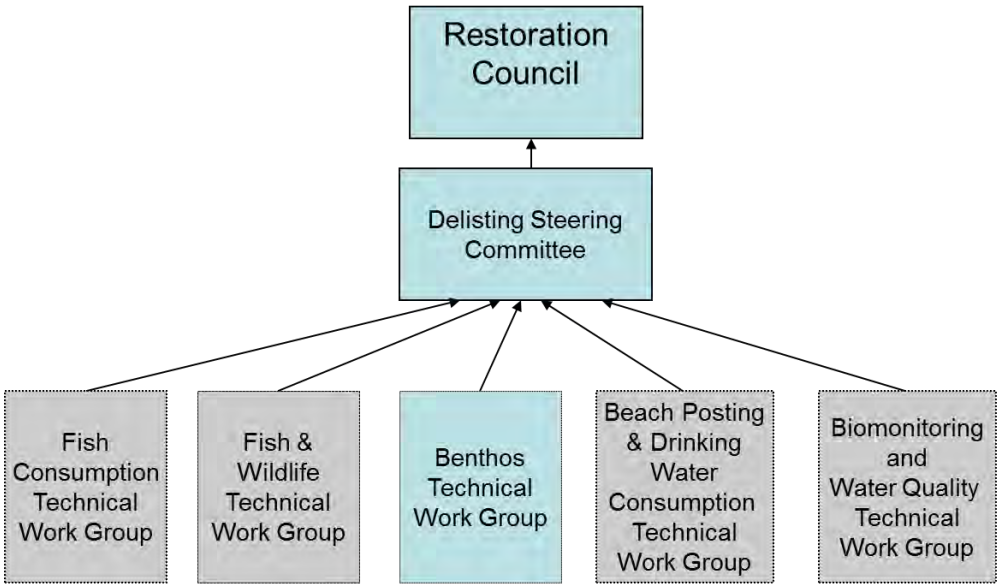
Whittaker, R.H., & Fairbanks, C.W. 1958. A study of plankton copepod communities in the Columbia Basin, southeastern Washington. Ecology 39: 46-56.

APPENDIX A: List of Abbreviations and Glossary

AOC	Area of Concern
Benthos	Benthic or bottom living invertebrates
BQ	Bay of Quinte
BQ RAP	Bay of Quinte Remedial Action Plan
BUI	Beneficial Use Impairment
DFO	Department of Fisheries and Oceans Canada
Dreissena	Zebra and quagga mussels (*Dreissena polymorpha, D. rostriformis bugensis*)
Macroinvertebrates	Fauna without backbones which are large enough to be captured in a sieve/net with a screen of 0.5 mm mesh.
PCB	Polychlorinated biphenyls
RAP	Remedial Action Plan
Taxon Richness	Taxon, or species, richness is simply a count of the number of different species, and it does not take into account the abundances of the species or their relative abundance distributions.

APPENDIX B: Contributors, Technical Reviewers, Approvals

The Bay of Quinte 'Degradation of Benthos' BUI Redesignation Report is a synthesis of environmental assessments undertaken by scientists to determine whether the Bay of Quinte is meeting the delisting criteria for the BUI. Each of these scientists belongs to the Bay of Quinte Benthos Technical Work Group. The Technical Work Group is also responsible for reviewing the benthos criteria and assessment reports and providing their expert recommendations to the Delisting Steering Committee. The Delisting Steering Committee provides an additional layer of accountability, ensuring that the appropriate documentation and data substantiate recommendations to the Bay of Quinte RAP Restoration Council that delisting targets and criteria have been met for impaired beneficial uses. The Restoration Council is the body which oversees implementation of the Bay of Quinte Remedial Action Plan, and which ultimately recommends delisting to ECCC and MOECC.



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- Glenda Rodgers, General Manager, Lower Trent Conservation Authority

Recommendation that criterion #2 has been achieved was approved by the Bay of Quinte AOC Benthos Technical Work Group on Sept 17, 2013:

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The BUI Redesignation Report was approved by the Bay of Quinte Benthos Technical Work Group and the Delisting Steering Committee on XXXX:

The BUI Redesignation Report was approved for submission to the governments of Canada and Ontario by the Restoration Council on XXXXXXX.

APPENDIX C: Communications

- to be completed